Project 5

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Results

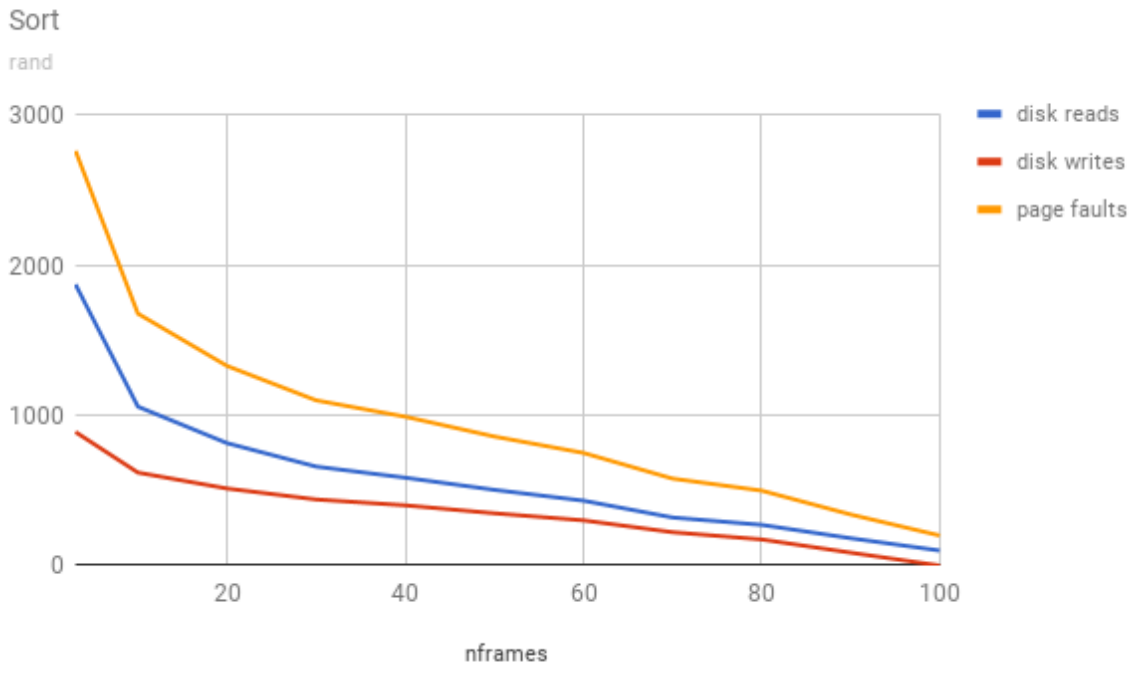
The following tests were run with 100 pages and 75, 50 or 25 frames. The program was run on student00, which has twelve of the Six-Core AMD Opteron(tm) Processor 2431, with 6 cpu cores each and a cpu MHz of 2393.717. The command line arguments run were of the format: `./virtmem 100 75 rand sort`.

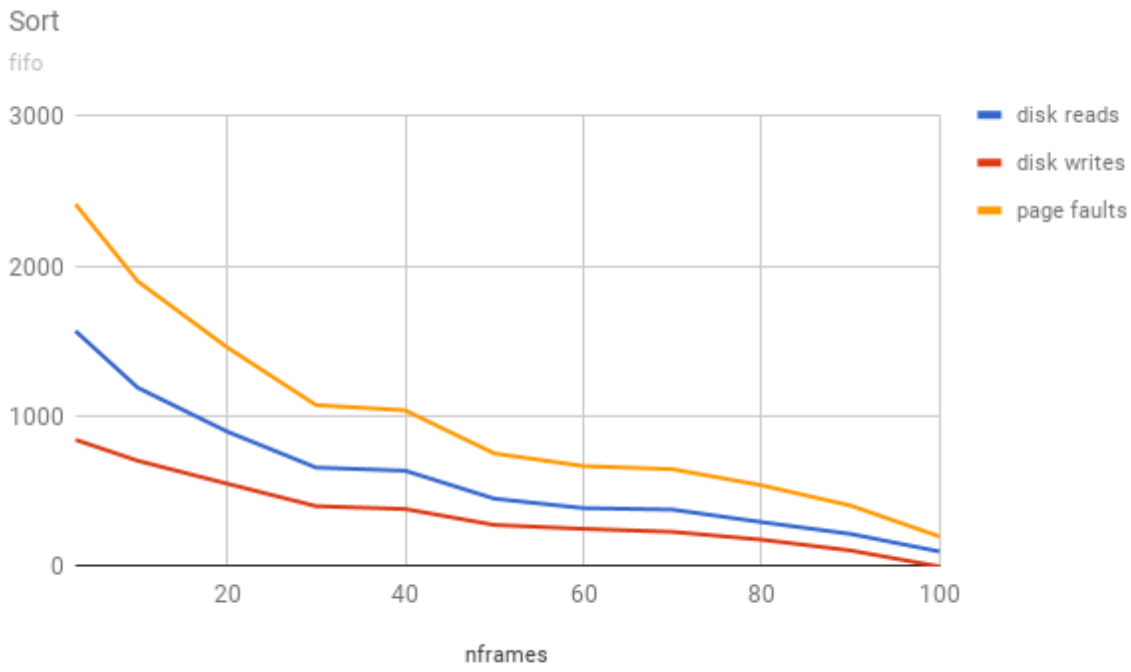
A shell script was written to run multiple commands, `run_virtmem.sh`, which can be run with the command: `./run_virtmem.sh rand sort` in order to run the virtmem function with the rand algorithm and sort program with 100 pages and between 3-100 frames.

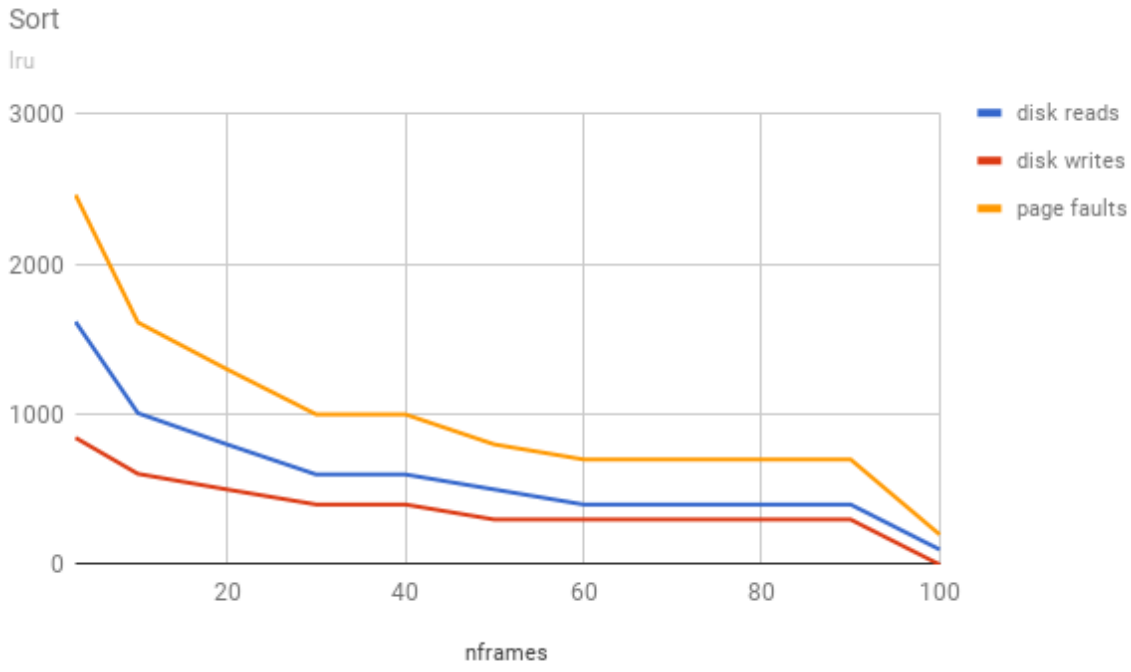
Further arguments run changed out `rand` for `fifo` or `custom` and `sort` for `scan` or `focus`.

Graphs

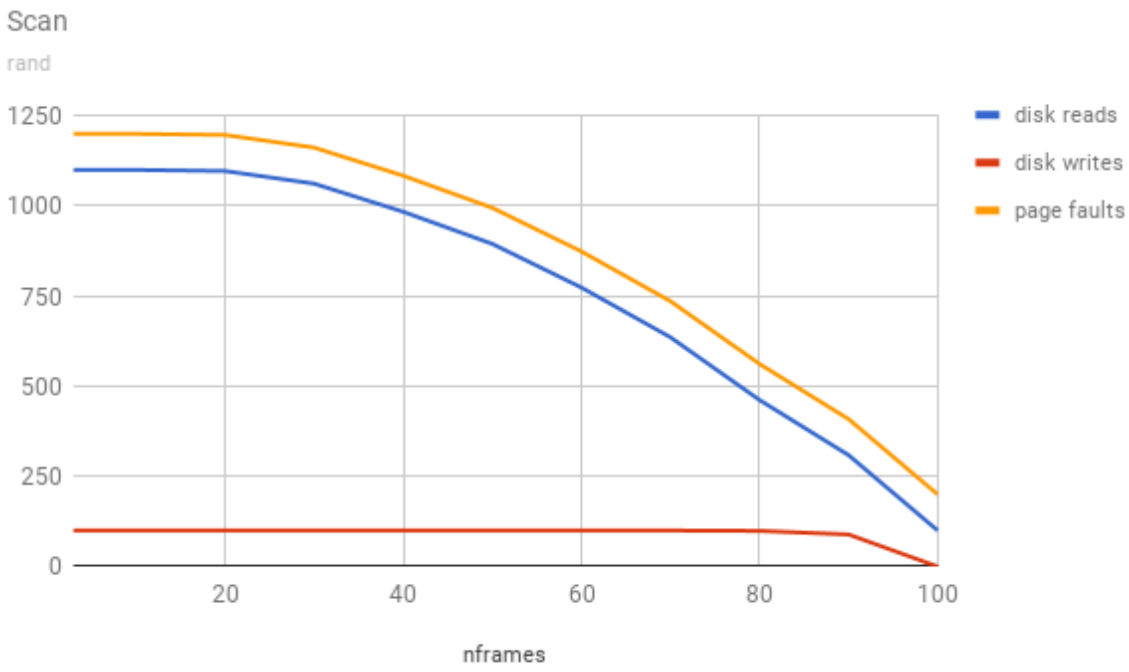
Sort

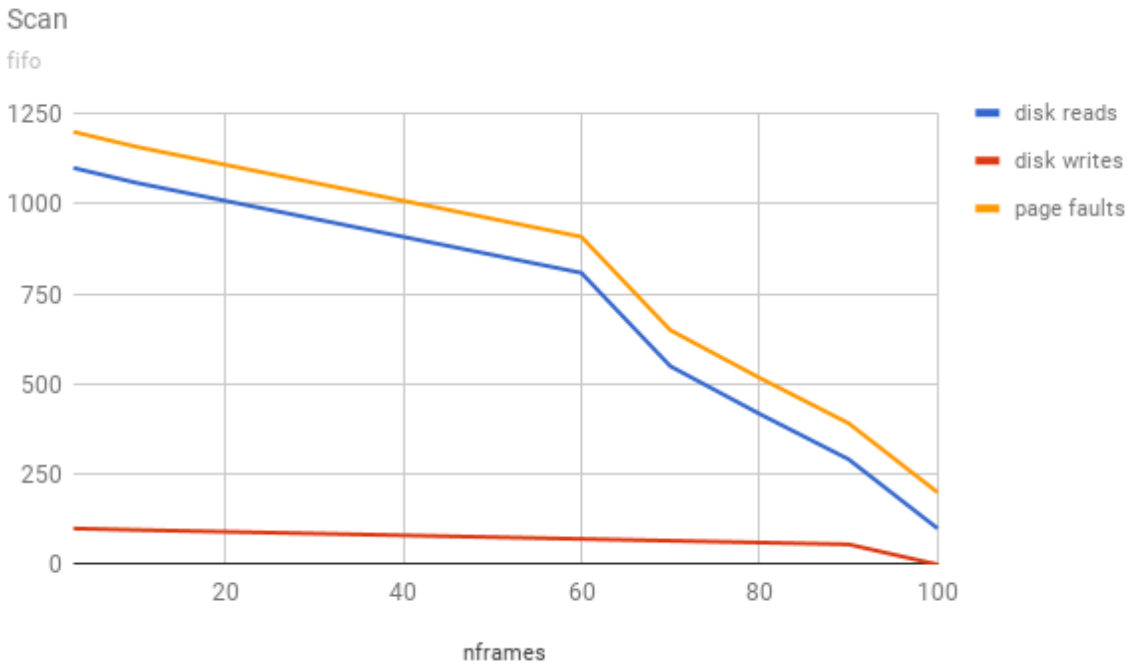


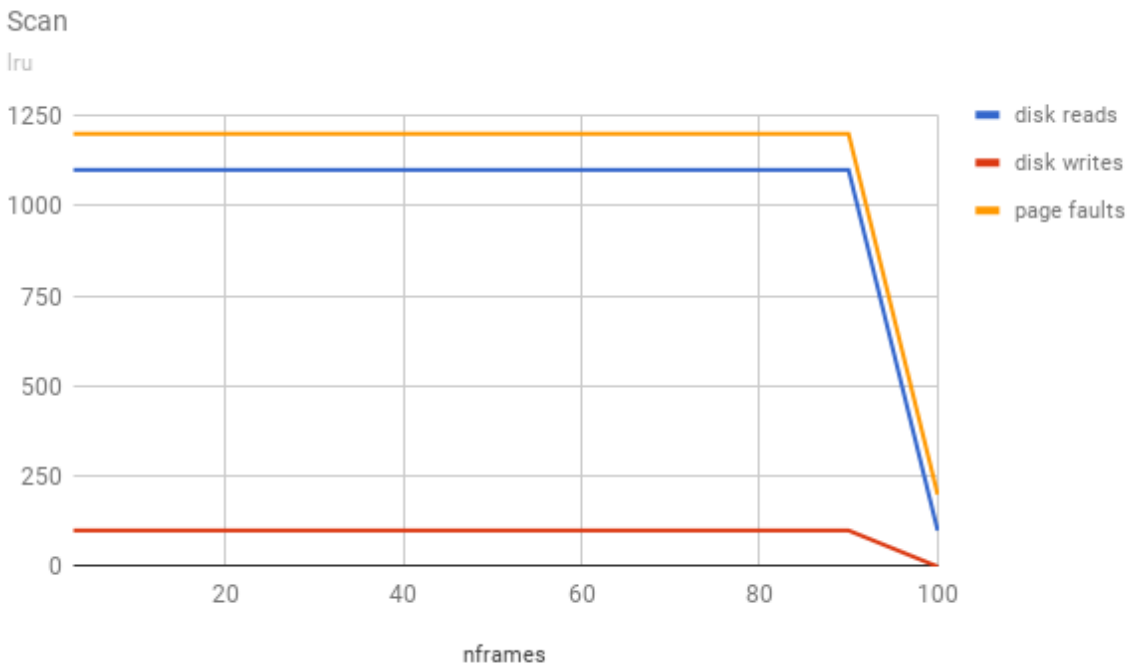

Sort
fifo
3000
2000
1000
0
20
40
60
80
100
nframes
disk reads
disk writes
page faults


Sort
lru
3000
2000
1000
0
20
40
60
80
100
nframes
disk reads
disk writes
page faults

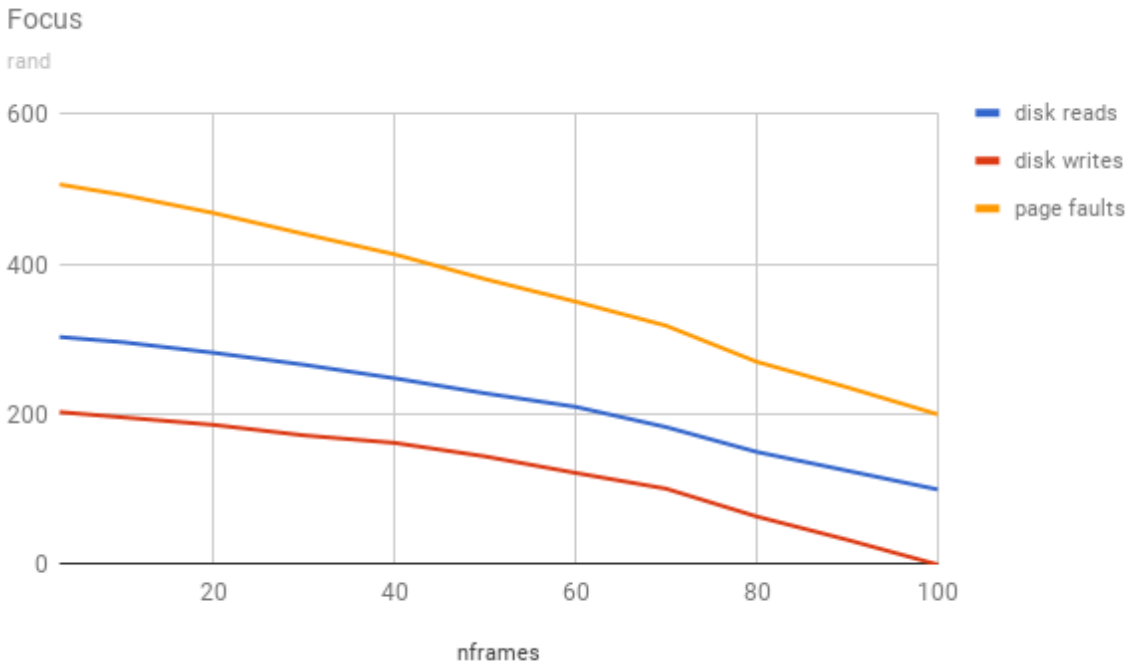
Scan

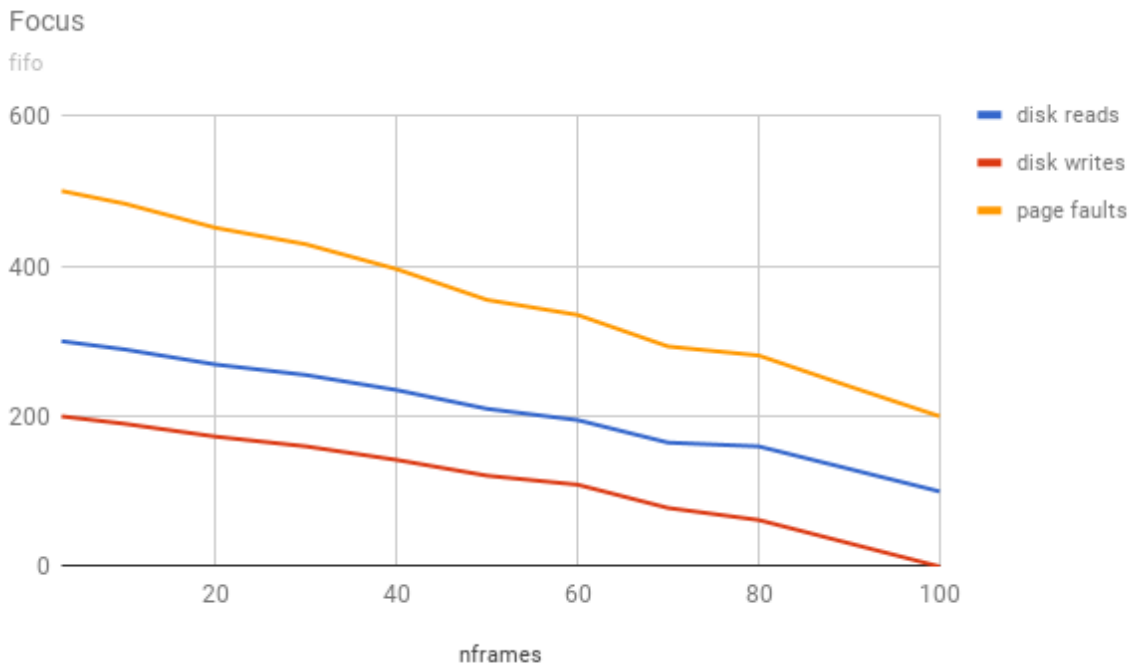

Scan
rand
1250
1000
750
500
250
0
20
40
60
80
100
nframes
disk reads
disk writes
page faults

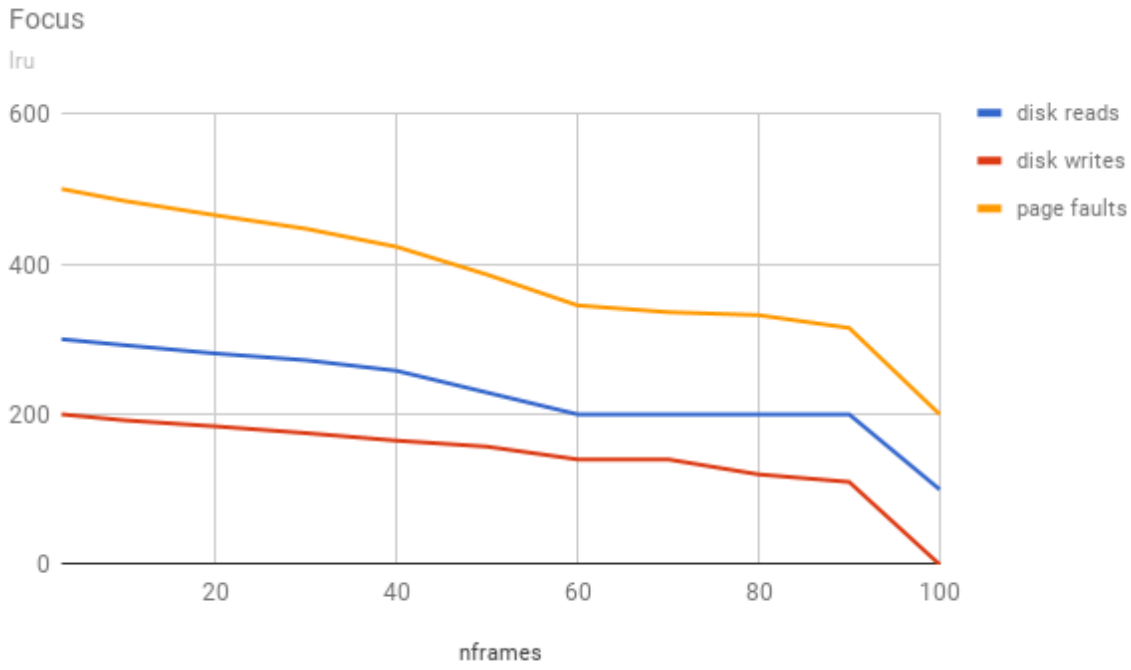

Scan
fifo
1250
1000
750
500
250
0
20
40
60
80
100
nframes
disk reads
disk writes
page faults


Scan
lru
1250
1000
750
500
250
0
20
40
60
80
100
nframes
disk reads
disk writes
page faults

Focus


Focus
rand
600
400
200
0
20
40
60
80
100
nframes
disk reads
disk writes
page faults





Analysis

Page Fault

If the frame size was equal to the number of pages, then there would be a page fault when first attempting to access data, and then another fault when reading. Therefore, the number of page faults in this case was equal to the number of pages/frames times two.

For the sorting operation, when the algorithm used was rand, the number of page faults increased exponentially from 20 to 3 frames, and decreased relatively linearly from 20 to 100 frames. This was slightly less efficient than the fifo algorithm, since less frames for the rand operation meant that there was a higher chance that the same frame would be replaced multiple times without switching the previous page reference for another one, since the probability of choosing a frame increases when there are less frames. For sorting, the program uses the quick sort algorithm, which divides elements according to a pivot value and sorts recursively. This algorithm reuses that pivot value in each iteration, but also accesses other elements to compare against that pivot value. Therefore, having about 50 frames would be the maximum efficiency for algorithms that aren't random, as qsort at its best divides subsets in half on the pivot value, as seen in the fifo and lru graphs, where the lines are relatively constant from 50 to 90 frames.

For the scan operation, the number of page faults did not improve for rand from 3 to 20 frames, but was relatively linear when more frames were added. For fifo, the number of page faults was linear from 3 to 60, and then increased a bit more dramatically when more frames past 60 were added. The lru algorithm performed the poorest for the scan operation, with the number of page faults not decreasing at all except when the number of frames equaled the number of pages. The lru program performed poorly since the sum value must have been overwritten repeatedly by the addition of new values in the array used for the scan program. At each of the algorithm's least efficient number of frames (3 frames for all), there were 1200 page faults. The scan program created an array of size proportional to the number of pages, and then accessed all elements in that array 10 times. Therefore, since there were 100 pages, there would have been 200 faults when first creating the array, and another 1000 on accessing the 100 elements 10 times.

For the focus function, the number of page faults for rand and fifo followed the same linear decreasing trend. For the lru algorithm, the trend was slighly less dramatic of a slope, though the general trend was the same. There were around 500 page faults when 3 frames were used, decreasing to 200 with 100 frames. The 500 faults can be explained by how the focus program works by using an array proportional to the number of pages (generating two page faults for every element first created), and accessing each data index from that array three times in the code (with another page fault each). When data is accessed but has been overwritten in physical memory, as will occur if nframes doesn't equal npages, a page fault will be thrown, a number that will go down when there are more frames and therefore less of a need to overwrite existing data.

Disk Access

If the frame size was equal to the number of pages, then all data was able to fit in the table, and therefore no disk writes had to be made. To load the data into the page table, a disk read had to be made, and so the number of pages requested was equal to the number of disk reads in this particular case.

For the sorting algorithm, there was about double the number of disk reads as disk writes, indicating that when data had to be written to disk, it was reused again later on in the program. This makes sense considering the nature of quick sort, which combines smaller sorted partitions, an operation that requires for elements that had been compared previously to be accessed once more. There was a similar trend as found in page faults, where the number of disk accesses was exponential under 20, and fairly constant over 50, especially for the lru algorithm. The lru algorithm was not too much more efficient than fifo, since elements that had not been accessed in a while would need to be accessed again for the sorting algorithm to work.

Disk writes were much lower for scan than for the focus or sort algorithms. For the rand and lru algorithms, the number of disk writes was fairly constant at 100, indicating that every index of the array used in the scan program had to be written to disk once. The fifo algorithm performed the best in terms of disk writes, showing a constant decrease of about five less writes for every 10 frames added up to 90 frames, with none written at 100. This indicates that data was kept in physical memory without having to be written to disk when more frames were added. The number of disk reads were proportional to the number of page fauts, and all trend lines closely followed lines plotted for page faults. This indicates that almost every time there was a page fault, there was also a disk read, indicating that the data required for the operation was not stored in the physical memory frames. The reason for the low number of disk writes is due to the nature of scan, which creates an array and then scans through that array and adds up a total. Since the data itself is not modified after creation, no additional disk writes are necessary except for incrementing the sum value. The lru program performed poorly since the sum value must have been overwritten repeatedly by the addition of new values in the array. The fifo and rand algorithms improved with more frames as expected, since the array was of length npages*PAGE_SIZE, so the more frames there were, the less often the disk had to be accessed for data, since the info could be stored in virtual memory.

The focus program had about 200 less disk reads as page faults, and about 100 less writes as reads for all three of the algorithms. The focus program first creates an array of size 100, then writes to each index 100 times, before summing the data. Therefore the data is written to 200 times for each index on the disk if removed from virtual memory, and read 100 times more than that due to how the a sum is also taken. This is reflected in the graph where 3 frames are used, with each algorithm generating 300 disk reads and 200 disk writes. When more frames are added, the number of reads and writes decreases relatively linearly. Since data is accessed sequentially multiple times, it is guaranteed that no matter how efficient an algorithm, data will have to be written to disk and then read back to physical memory, so even with 90 frames there are 30 disk writes for the rand and fifo algorithms. The lru algorithm did not perform as well, making 110 disk writes with 90 frames, and a constant 200 disk reads from 60 to 90 frames. This performance can be explained by how the lru algorithm had an additional array used in the program itself that also took up space in the physical memory, which was used to track the last resource used in the frame table.

Custom Strategy

The custom algorithm used was the least recently used algorithm, in which what was untouched for the longest time would be replaced once the page table was full. This algorithm is based on the assumption that data that has been used recently will be used again, so old data was replaced as it was therefore assumed that data that had not been touched in a while would not be as likely to be used again. In order to keep track of the information required for the last recently used algorithm, an array was created to track when a frame was accessed. On every page fault, each index in the array was incremented, while the frame that was accessed in that particular page fault was set to 0. Therefore, once the time came to change out a page in the array, the index with the largest value in the array would be the least recently accessed.